

Amendments to the Claims

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1. (Currently amended) A method of arranging at least one workpiece and one or more workpiece processing devices in a manufacturing cell using a programmable computer with a database, each said device either consisting of a rigid body or comprising two or more rigid bodies connected by kinematic joints, one of which bodies is declared to be the base link of said device, and each said workpiece and said rigid bodies having one or more virtual embedded coordinate systems, said method comprising
 - entering a geometric description of said manufacturing cell in said database;
 - entering a geometric description for each said workpiece and workpiece processing device including kinematic and limit of motion data for each said joint of said devices into said database;
 - entering in said database an initial position and orientation of each workpiece and each base link, in which location each is either attached to ground in the cell or to another rigid body;
 - entering in said database a tree structure of program steps, the root node of said tree containing a value for each joint of each device in said, manufacturing cell at some initial time, and each child node of a particular node in said tree representing an alternative motion in terms of a list of devices which will move should that alternative be chosen, and containing for each joint of each such moving device a value to be attained at the completion of the motion;
 - entering in said database identification of attracting pairs of coordinate systems, each member of the attracting pair being one of the embedded coordinate systems of said workpiece or said rigid bodies of said devices at a specified program step;
 - entering in said database identification of repelling pairs, each member of which is a workpiece or device in said manufacturing cell;

identifying in said database those workpieces and base links whose locations are to be moved from their initial positions and orientations and those joints whose values are to be adjusted, such movements and adjustments being optimized with respect to said attracting pairs and repelling pairs; and

subjecting prospective locations and joint values to a mathematical optimization analysis to achieve an arrangement of each said workpiece and devices in said cell in which said attracting pairs of coordinate systems are coincident, said repelling pairs are separated, and said joint values all lie within said limits of motion.

2. (Original) A method as recited in claim 1 comprising using computer graphics to display said manufacturing cell, workpieces, processing devices, attracting pairs and repelling pairs, and to indicate those workpieces, base links and joints which are subject to optimization.

3. (Original) A method as recited in claim 1 wherein said computer comprises a graphical user interface and said method comprises using said graphical user interface to add, delete or modify the entering of said geometric descriptions and positions and orientations of workpieces and devices in the said database, allowing said manufacturing cell arrangement to be created iteratively and allowing complex arrangements to be developed in several stages of increasing complexity.

4. (Original) A method as recited in claim 1 comprising integrating said method with computer simulation software so that any sequence of motion alternatives contained in said tree of program steps can be selected and the corresponding continuous motion through the sequence can be animated using computer graphics.

5. (Original) A method as recited in claim 1 comprising assigning said attracting pairs as consisting of attraction between the origin points of the coordinate systems of said pairs, leaving the relative orientation of the coordinate systems free.

6. (Original) A method as recited in claim 1 comprising assigning said attracting pairs as consisting of attraction between the origin points of the coordinate systems and attraction between a secondary pair of points of said systems, said secondary points being a specified non-zero distance along a specified direction of the said coordinate systems, thus causing the line segment from origin to secondary point of the respective bodies to align while leaving rotation about that line segment free.

7. (Original) A method as recited in claim 1 comprising assigning said attracting pairs as consisting of attraction between the origin points of the coordinate systems of said attracting pairs and attraction between two or more additional pairs of points of each of said systems, forming congruent geometric entities, so that bringing the corresponding points into coincidence fully constrains the relative orientation of said attracting pairs.

8. (Original) A method as recited in claim 1 wherein the function to be optimized is formed as a weighted sum of contributions from each attracting pair, repelling pair, and joint value whereby the attraction of an attracting pair is the sum of the contribution of each designated point pair of the coordinate systems of the attracting pairs and the contribution of a single point pair is a continuous, monotonically increasing function of the Euclidean distance between the points; the contribution of a repelling pair is zero if the bodies are separated by more than a specified upper distance, is infinity if the bodies interfere or are separated by less than a specified minimum distance, and is a continuous, monotonically decreasing function of the separation distance; and the contribution of a joint value is infinite if the value exceeds the upper or lower joint limit and monotonically decreases to zero as the joint value moves into the allowed joint limit range, such that a function value of zero implies that all attracting pairs are coincident, all repelling pairs are separated by at least the specified upper distance, and all joint values are within their respective joint limits.

9. (Original) A method as recited in claim 1 wherein when the location of a workpiece or base link is selected for optimization, the freedom to adjust the position

and orientation can be restricted to be any subset among translation along and rotation about the three coordinate directions of a coordinate system selected from among those embedded in the body or in the body to which it is attached.
